(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 November 2000 (30.11.2000)

PCT

(10) International Publication Number
WO 00/72240 A1

(51) International Patent Classification[7]: G06K 11/12

(21) International Application Number: PCT/GB00/01552

(22) International Filing Date: 4 May 2000 (04.05.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/315,139 20 May 1999 (20.05.1999) US

(63) Related by continuation (CON) or continuation-in-part (CIP) to earlier application:
US 09/315,139 (CIP)
Filed on 20 May 1999 (20.05.1999)

(71) Applicant (*for all designated States except US*): ELECTROTEXTILES COMPANY LIMITED [GB/GB]; 2 Bloomsbury Street, London WC1B 3ST (GB).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): SANDBACH, David, Lee [GB/GB]; Flat C, 9 Westbourne Road, London N7 8AR (GB).

(74) Agent: ATKINSON, Ralph; Atkinson Burrington, 27-29 President Buildings, Firth Way, Sheffield S4 7UR (GB).

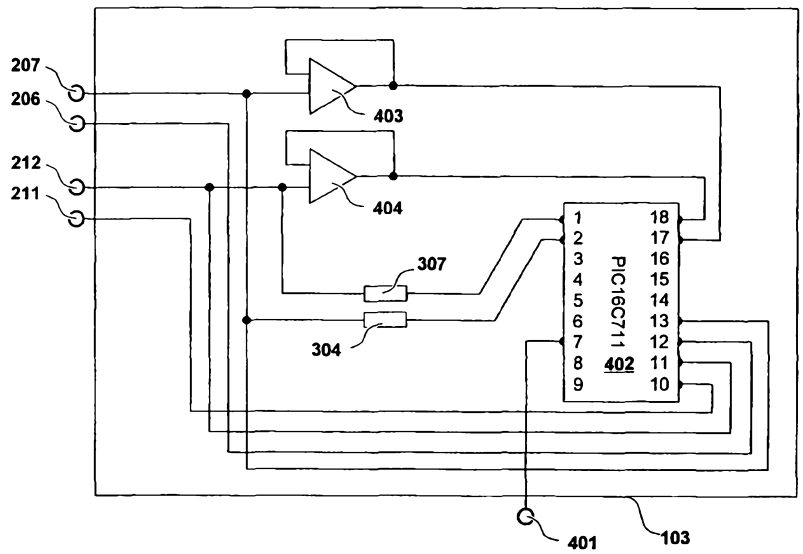
(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

[Continued on next page]

(54) Title: DETECTING MECHANICAL INTERACTIONS



(57) **Abstract:** A fabric-made position detector is disclosed, having a first fabric electrically conducting layer and a second fabric electrically conducting layer. The first electrically conducting layer has a first electrical contact and a second electrical contact and a second electrically conducting layer has a third electrically conducting contact and a fourth electrically conducting contact. Potential is applied across the first contact and the third contact to produce a first current and a potential is then applied across the second contact and the fourth contact to produce a second current. The first current is measured to produce a first current value and the second current is measured to produce a second current value. The first value and the second value are processed in combination to produce a property value indicating a property of the mechanical interaction.

WO 00/72240 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Detecting Mechanical Interactions

Reference to related applications

The present invention was made by Mr David Lee Sandbach who is resident in the United Kingdom. A permit to file a first application outside the United Kingdom under section 23(1) of the patents act 1977 was obtained on 19 May 1999. The present application claims priority from United States patent application 09/315,139 filed on 20 May 1999. With respect to the United States designation, the present application is filed as a continuation in part.

Field of the Invention

The present invention relates to detecting a mechanical interaction with respect to a position detecting device, wherein the position detecting device is configured to detect the position of a mechanical interaction by measuring electrical potential applied across electrically conducting layers.

Background of the Invention

A position sensor for detecting the position of a mechanical interaction is described in European patent publication 0 989 509, equivalent to United States patent application 09/298,172, Korean patent application number 99-40363, Japanese patent application number 11-2,513 and Australian patent application 48770/99, all assigned to the present assignee. The position detector is configured to determine the position of a mechanical interaction. In addition, the detector is also configured to measure the extent of the mechanical interaction in which the representation of the extent of a mechanical interaction is usually made up of components representing the force of the mechanical interaction and the area over which the mechanical interaction takes effect.

A problem with the known position detector is that the extent measurements are extremely accurate at positions away from edge of the detector. However, as positions approach the edges of the detector and particularly when positions approach corners of the detector the accuracy of the extent of the mechanical interaction measurements, becomes relatively inaccurate.

Brief Summary of the Invention

According to a first aspect of the present invention, there is provided a fabric-made position detector, having a first fabric electrically conducting layer; a second fabric electrically conducting layer, wherein said first electrically conducting layer has a first electrical contact and a second electrical contact and said second electrically conducting layer has a third electrically conducting contact and a fourth electrically conducting contact; potential applying means for applying potential across said first contact and said third contact to produce a first current and for applying a potential across said second contact and said fourth contact to produce a second current; current measuring means for measuring said first current to produce a first current value and for measuring said second current to produce a second current value; and processing means configured to produce a property value indicating a property of a mechanical interaction by processing said first current value in combination with said second current value.

According to a second aspect of the present invention, there is provided a fabric-made position detector, having a first fabric electrically conducting layer; a second fabric electrically conducting layer, wherein said first electrically conducting layer has a first electrical contact and a second electrical contact and said second electrically conducting layer has a third electrically conducting contact and a fourth electrically conducting contact; potential applying means for applying potential across said first contact and said third contact to produce a first current and for applying a potential across said second contact and said fourth contact to produce a second current; current measuring means for measuring said first current to produce a first current value and for measuring said second current to produce a second current value; and processing means configured to produce a property value indicating a property of a mechanical interaction by processing said first current value in combination with said second current value.

An advantage of said first aspect is that the accuracy of said property value is enhanced significantly by deriving a result from the combination of two measurements. Inaccuracies may still occur at edges of the device when using isotropic conducting layers.

In a preferred embodiment, the fabric-made position detector is configured such that said fabric electrically conducting layer and/or said second fabric electrically conducting layer have different conductivites in different directions. Preferably, layer conductivity of the first layer in a first direction connecting said first contact with said second contact is lower than the conductivity in a second direction perpendicular to said first direction.

The use of non-isotropic layers facilitates a more accurate analysis and modelling of layer resistivities. Consequently, in a preferred embodiment, the property value is determined by combing a reciprocal of said first current value with a reciprocal of said second current value.

According to a second aspect of the present invention, there is provided a method of detecting a mechanical interaction with respect to a position detecting device, wherein said position detecting device is configured to detect the position of the mechanical interaction by measuring electrical potentials applied across electrically conducting layers, characterised by the steps of measuring a first current when an electrically potential is applied between a first contact and a first conducting layer and third contact of a second conducting layer while disconnecting connections to a second contact of the first conducting layer and a fourth contact of said second conducting layer; measuring the second current when an electrical potential is applied between said second and said fourth contacts while disconnecting connections to said first and said third contacts; and processing said first current measurements in combination with said second current measurement to derive an output indicative of a characteristic of said mechanical interaction.

Brief Description of the Several Views of the Drawings

Figure 1 shows a position sensor embodying the present invention;

Figure 2 details the sensor shown in *Figure 1*;

Figure 3 illustrates upper and lower fabric layers of the sensor shown in *Figure 2*;

Figure 4 details the interface circuit shown in *Figure 1*;

Figure 5 illustrates a program executed by the processor of the interface circuit;

Figures 6, *7* and *8* detail procedures identified in the program illustrated in *Figure 5*;

Figure 9 illustrates an arrangement similar to that shown in *Figure 2*, showing lines of current flux;

Figures 10 and *10b* illustrate a two dimensional representation of the arrangement shown in *Figure 9*;

Figure 11 shows a revised model for resistances;

Figure 12 shows the upper and lower fabric layers identified in *Figure 2*;

Figure 13 identifies alternative fabric layers to those shown in *Figure 12*;

Figures 14a and *14b* illustrate flux densities for the fabric layers identified in *Figure 12*.

Best Mode for Carrying Out the Invention

A position sensor **101** embodying the present invention is shown in *Figure 1*, fabricated from fabric layers of a material and configured to rest on a flat or curvilinear surface. The sensor responds to mechanical interactions and in the specific example shown in *Figure 1*, these mechanical interactions take the form of manual pressure being applied by users in order to make selections.

In the example shown in *Figure 1*, the sensor **101** provides a substitute for a television, video recorder or satellite television remote control. In preference to a solid object providing a series of buttons, the detector is substantially fabric and may adopt a shape defined by soft furnishing. In the example shown, the detector **101** is configured as a separate item but in an alternative configuration the detector could be included as part of a soft furnishing item, such as a chair or sofa **102**.

The sensor **101** includes an interface circuit **103** arranged to respond to mechanical interactions and to provide co-ordinate and pressure data over an interface line **104** to a processing device **105**. In response to mechanical interaction effected by a user, positional data is conveyed to processing device **105** that in turn transmits infra-red data via an infra-red transmitter **106** to audio-visual equipment, such as television **107**. In an alternative embodiment, the interface circuit and the infra-red transmitter are miniaturised and included as part of the fabric detector itself.

An example of a sensor of the type shown in *Figure 1* is shown in exploded view in *Figure 2*. The sensor comprises two woven outer fabric layers **201** and **202**, separated by a central layer **203**. The central layer **203** is a layer of knitted fabric which may be made from conductive fibre only. Such fibre may, for example be a carbon coated nylon fibre. However, preferably a yarn is used in the knit which is a mixture of insulating and conductive fibres.

The first insulating mesh layer **204** is located between the upper fabric layer **201** and the central layer **203** and a second insulating mesh layer **205** is located between the lower fabric layer **202** and the central layer **203**. The insulating mesh layers **204** and **205** are made from polyester fabric of a warp knit construction. Fabric of this type is readily available and may be used in applications such as mosquito netting.

Electrically conductive fibres are used when weaving layer **201** and **202** such that layers **201** and **202** define two electrically conductive layers. Alternatively, layers **201** and **202** may be constructed from non-woven (felted) or knitted fabrics or as a composite structure. However, in each of these alternative applications, electrically conductive fibres are included in the production of the fabric, thereby providing electrically conductive layers.

Two electrical connectors **206** and **207** are located on a rectangular insulating stripe **208** that is positioned along one edge of fabric layer **201**. The insulating stripe is produced by printing insulating ink on to the fabric. Alternatively, insulating adhesive tape could be used. The connectors **206** and **207** provide a means of connection from the interface circuit **203** to low resistance elements **209** and **210** respectively. Low resistance elements are fabricated from fabric coated with metals such as nickel or silver. Material of this type is readily available and is used for shielding equipment from electromagnetic interference. The low resistance elements are attached to the conductive fabric layer **201** and to the insulating stripe **208** by conductive adhesive, such as a pressure sensitive acrylic adhesive containing metalised particles. Consequently, portions **216** and **217** of the low resistance elements **209** and **210** make electrical contact with the conductive fibres of layer **201** along two of it's opposing edges.

The conducting adhesive ensures a bond is formed between the low resistance elements **209** and **210** and the conductive fibres. Due to this bond, the resistance between the conductive fibres and the connection portions **216** and **217** remains unaffected by folding or flexing the layers **201**. This is important as, otherwise, a dry joint would exist connecting **216** and **217** to **201** and a varying resistance at the connections would lead to unreliable and possibly unstable measurements when the sensor is operated.

Alternatively, the low resistance elements **209** and **210** are formed by attaching, for example by sewing, a low resistance fibre to the layer **201** and then printing a conductive adhesive or compound onto it and the layer **201**. Alternatively, the lower resistance elements may be produced by printing an elastomeric material containing conductive particles onto the layer **201**. All of the alternative methods described provide a suitable bond, forming a reliable electrical connection or wet joint.

The lower fabric layer **202** has a similar construction to the upper fabric layer **201**, having connectors **211** and **212** located on insulating stripe **213**. The connectors **211** and **212** provide a means for connecting interface circuit **103** with low resistance elements **214** and **215** respectively. The two layers **201** and **202** are rectangular and the construction of layer **202** is rotated 90 degrees from that of layer **201**. Thus, contacting portions **216** and **217** contact the conductive fibres in layer **201** along two opposing edges and the low resistance elements **214** and **215** have contacting portions **218** and **219** that contact the conductive fibres in layer **202** along the alternate opposing edges.

A procedure for measuring the position and the extend of a force supplied to a position sensor consisting of fabric layers as described herein, is illustrated in *Figure 3*. The outer conductive layers **201** and **202** are represented schematically by potentiometers **301** and **302** at **380** and the resistance of the conductive path between the outer layers at the location of a mechanical interaction is represented by variable resistor **303**. A first measurement is shown in which 5 volts are applied to connector **211** while connector **212** remains disconnected. Connector **207** is connected to ground via a resistor **304** of known value. Thus, current flows from connector **211** through a first part of layer **202** indicated by first part **305** of potentiometer **302**, through the conductive path indicated by variable resistor **303** having a resistance Rv, through a first part of layer **201**, indicated by a first part **306** of potentiometer **301** and through the known resistor **304**. The voltage V1 at connector **207** is measured and since this is equal to the voltage drop across resistor **304**, voltage V1 is directly proportional to the current flowing from connector **211**.

A second measurement is shown at **390** in which five volts are applied to connector **206**, while connector **207** is disconnected. Connector **212** is connected to ground via a resistor **307** of known resistance. The voltage V2 dropped across resistor **307** is measured. This voltage V2 is directly proportional to the current flowing through a second part of layer **201** indicated by a second part **308** of potentiometer **301**, through the conductive path indicated by variable resistor **303** having resistance Rv, through a second part of layer **202** indicated by a second part **309** of potentiometer **302** and through resistor **307**.

The sum of the resistance of first part **306** and second part **308** of potentiometer **301** is approximately equal to the resistance between connectors **206** and **207** on layer **201** and is therefore substantially constant during the measurements, since they occur in rapid succession. Similarly, the sum of the resistance of the first part **305** and the second part **309** of potentiometer **302** is approximately equal to the resistance between connector **211** and connector **212** on layer **202** and is also substantially constant during the measurements. As a result, a relationship **310** exists between the resistance Rv of the conductive path between the outer layers and the measured voltages V1 and V2. That is to say, the resistance Rv between the outer layers is proportional to the sum of the reciprocal of voltages V1 and the reciprocal of voltages V2.

Useful results may be obtained by merely averaging these voltages but greater accuracy is obtained if account is taken of relationship **310** when designing operations to be executed within control hardware.

The resistance value Rv depends upon the area of the mechanical interaction and the pressure or force applied at the mechanical interaction, as illustrated by relationship **311**. Thus, from the voltage measurements V1 and V2, it is possible to derive an indication of the area over which the force is applied or an indication of the area and the applied force that has been applied, dependent upon the type of sensor being used. Such an indication is substantially independent of the position of the mechanical interaction on the sensor.

A third measurement is shown at **391**. Five volts are applied to connector **212** while connector **211** is grounded, thereby creating a potential gradient across layer **202**. A voltage measurement is made at connector **207** using a high impedance device and so the voltage appearing on layer **202** at the position of the applied force is determined. This voltage, V3 is directly proportional to the distance of the centre of the applied force from connecting portion **218** and indicates its x-axis position.

A fourth measurement is shown at **392**. Five volts are applied to connector **207** and connector **206** is grounded. A voltage measurement is made of voltage V4 appearing at connector **212**. Voltage V4 is directly proportional to the distance of the centre of the applied force from connecting portion **216** and indicates its y-axis position. Consequently, voltage V3 and voltage V4 provide information as to the two-dimensional position of the applied force on the sensor. Consequently, voltages V3 and V4 represent x and y values respectively for the centre of the position of the applied force.

Interface circuit **103** is detailed in *Figure 4*. The interface circuit supplies voltages to connectors **206**, **207**, **211** and **212** and measures voltages V1, V2, V3 and V4. The interface circuit also provides output values at serial communication output **401**, consisting of values corresponding to the xy two dimensional positions of the mechanical interaction of the sensor and the z value depending upon the area of the mechanical interaction or the area and force of the mechanical interaction.

When designing an interface circuit, resistors **304** and **307** are chosen according to the resistance of the sensor as measured from one connector on layer **201** to another connector on layer **202**, while a typical target pressure is applied to the sensor. A value of ten Kohms is typical for resistors **304** and **307**.

The measurement process is controlled by a program running in a peripheral interface controller (PIC) **402**, such as type PIC 16C711. As well as being capable of supplying the required output voltages of pins one, two, ten, eleven, twelve and thirteen, the PIC **402** includes an analogue to digital converter that it uses to process analogue voltages received at input pins seventeen and eighteen. Input pins seventeen and eighteen receive outputs from high impedance buffers **403** and **404** respectively. Buffers **403** and **404** are half of a unity gain operational amplifier of type TL 062 and provide a high impedance buffer between the sensor output voltages and the PIC **402** input ports.

Processor **402** has an external crystal oscillator running at 4 Mhz connected across pins fifteen and sixteen. Positive five volts is applied to pin fourteen and pin five is connected to ground. Pin 4 (internal reset) is held at a positive five volts via a series resistor of 100 ohms.

The program executed by the PIC processor is illustrated in *Figure 5*. At step **501** the hardware is initialised and at step **502** circuit **103** measures values of voltages V1 and V2 and calculates the z value of the interaction.

At step **503** a question is asked as to whether the z data is greater than a predetermined value and if answered in the negative, the program returns to step **502**. Thus, the circuit measures z values until a z value greater than a predetermined value is detected.

If the answer to the question asked at step **503** is answer in the affirmative, the circuit measures voltages V1, V2, V3 and V4 and thereafter calculates a z value at step **504**.

At step **505** a question is asked as to whether the calculated z value is still above the predetermined value. If the question is answered in the affirmative, a further question is asked at step **506** as to whether enough samples have been obtained. Typically, between three and ten sets of samples are taken, with less samples being taken when a fast response time is required. If the question asked at step **506** is answered in the negative, the program returns to step **504** and a further set of measurements are made. When the question asked at step **506** is answered in the affirmative, or when the answer to the question asked at step **505** is answered in the negative, the program calculates average values of the samples of the voltages V3 and V4 and of the values of z which have been collected. Thus, the program measures a predetermined number of voltages before finding the average values, or if the z value drops below a predetermined value, the average values are calculated immediately. By using the average of a number of samples the effect of mains power electromagnetic interference or other such environmental noise may be minimised.

A relatively straightforward calculation to find an average value for the x values is to find the mean average of the maximum and minimum values of the stored values V3 thus presenting a smoothed value for x which is found by adding the maximum value stored for value V3 to the minimum value stored for V3 and dividing the result by two.

To further improve accuracy, values of x, y and z that differ by a large amount from their immediately preceding and immediately subsequent value are excluded from the calculations of the average. In addition, known method of eliminating mains electricity supply interference may be applied to signals received from the sensor.

At step **508** the average values for V3 and V4, representing xy positional co-ordinates and the average values for z data are supplied as outputs at the serial communication output **401**. The program then returns to step **502** and looks for an indication of a further mechanical interaction.

Step **501** is detailed in *Figure 6*. At step **601** interrupts are cleared and at step **602** pins seventeen and eighteen are set up as analogue to digital converter inputs. The microports of the PIC 16C711 may be configured as low impedance outputs or high impedance inputs. When in high impedance input mode, pins seventeen and eighteen can be programmed to connect via an internal multiplexer to the analogue to digital converter.

At step **603** the ports which are to be used as inputs or outputs are configured in their initial state. At step **604** all system variables are cleared and all interrupts are disabled.

Step **502** is detailed in *Figure 7*. At step **701** the ports corresponding to pins two and ten are reconfigured as output ports and at step **702** pin two is set to zero while pin ten is set to positive five volts. Thus, connector **207** is grounded via resistor **304** and five volts are applied to connector **211**. At step **703** a time delay of typically two hundred-and-fifty microseconds is provided for a typical sensor measuring a hundred millimetres by a hundred millimetres. This delay allows voltages to settle before the voltage at pin seventeen is measured and stored. Thus, voltage V1 present at connector **207** is measured at this step.

At step **705** pins two and ten are reconfigured as high impedance inputs while pins one and twelve are reconfigured as low impedance outputs. At step **706** the voltages on pins one and twelve are set to zero and positive five volts respectively. Thus, connector **212** is grounded via resistor **307** while five volts are applied to connector **206**.

A suitable time delay, equivalent to that at step **703** is provided at step **707** before the voltage at pin eighteen is measured and stored at step **708**. Thus, the voltage present on connector **212** is measured and stored as voltage V2. At steps **709** a z value is calculated for stored voltages V1 and V2 and then stored. Pins one and twelve are reconfigured back to their initial state as high impedance outputs at step **710**.

Step **504** is detailed in *Figure 8*. At step **801** a z value is collected in a substantially similar manner as performed at step **502**. At step **802** pins one and two are reconfigured as high impedance inputs and pins ten and eleven as low impedance outputs. At step **803** pin ten is set to zero volts and pin eleven is set to positive five volts. Thus, five volts are supplied to connector **212** while connector **211** is grounded. A delay is provided at step **804** (typically one millisecond for a device measuring 100 millimetres by 100 millimetres) to allow voltages in the sensor to settle before the voltage on pin seventeen is measured at step **805**. Therefore, a voltage V3 present on connector **207** is measured that provides an indication of the x position of the applied force.

Pins ten and eleven are reconfigured as high impedance inputs and pins 12 and 13 are reconfigured as low impedance outputs at step **806**. The voltage on pin 12 is set to zero while the voltage on pin 13 is set to five volts at step **807**. Thus, five volts are supplied to connector **207** while connector **206** is grounded.

A time delay is provided at step **808**, similar to that provided at step **804**, before the voltage appearing on pin 18 is measured at step **809**. Thus, a voltage V4 present on connector **212** is measured which provides an indication of the y position of the applied force. Pins 12 and 13 are then reconfigured back to their initial stage of high impedance inputs.

The procedures described with reference to *Figures 5 to 8* allow the interface circuit to make voltage measurements V3 and V4 which provide an indication of the position of the mechanical interaction applied to the fabric sensor. Similarly, measurements of voltages V1 and V2, that are proportional to currents passing through the sensor, provide information as to a second characteristic of the mechanical interaction. The second characteristic may, for example, be an area of interaction or, typically, a combination of area and force. Furthermore, the circuit combines the voltages V1 and V2 to determine a z value representative of the second characteristic.

The circuit **103** provides output data representative of x and y position of the applied force and the z value. However, in an alternative embodiment, the interface circuit provides output data corresponding to the measured voltages V1, V2, V3 and V4. In an alternative embodiment, sophisticated further processing is performed upon these voltages that may in turn be used to control other peripheral equipment. For example, as an alternative to having a separate control device for generating infra-red signals, as shown in *Figure 1*, all of this functionality could be enclosed within a single control circuit within the PIC processor **402** controlling the generation of infra-red signals. The arrangement therefore provides a fabric-made position detector with a first fabric electrically conducting layer and a second fabric electrically conducting layer. The first electrically conducting layer has a first electrical contact and a second electrical contact with the second electrically conducting layer having a similar third electrically conducting contact and a fourth electrically conducting contact. Potential is applied across the first contact and the third contact to produce a first current and then a potential is applied across the second contact and the fourth contact to produce a second current. Each of these currents are measured and then values are processed in order to produce an output indicative of a property of a mechanical interaction. In this way, more accurate results are obtained in preference to a system where only one current measurement is made.

When current flow takes place, current densities may be expressed graphically by lines of flux where the concentration of flux lines is greater in areas where the current density is greater. As is well known in the art, similar graphical representation may be produced by connecting equipotentials and, as is known, the equipotentials are perpendicular to the flux lines positions of intersection.

An arrangement similar to that shown in *Figure 2* is illustrated in *Figure 9* in which lines of current flux are shown passing through first conducting layer **201** with similar flux lines being shown in the second conducting layer **202**. The current flows between layers at a point of mechanical interaction **901**. A positive potential is applied to connector **211** resulting in current flow, as illustrated by flux line **902** flowing to the point of mechanical interaction **901**. Current passes through the central conducting layer **203** at the point of mechanical interaction and then flows across the first conducting layer **201**, as illustrated by flux line **903** to then sink through contact **207**.

A two dimensional representation of layer **201** and layer **202** is shown in *Figure 10a*. Most of the current reaches contact **207** via connecting portion **217**. However, some of the current passes through connecting portion **216** as illustrated by flux lines **1001**. This current then re-enters the conducting layer to return to contacting portion **217**, as illustrated by flux line **1002**. The contribution to the measured conductivity resulting from this effect is greater when the point of mechanical interaction is close to an edge of the detector and is particularly prevalent when the point of mechanical interaction is close to a corner of the detector.

A similar effect occurs on the lower conducting layer **202**. Thus, in addition to current being received directly from connecting portion **218**, as illustrated by flux lines **1003**, some of the current travels through connecting portion **219**, as illustrated by flux lines **1004** and **1005**.

A similar problem occurs when the current direction through the sensor is changed, as required by the present invention. However, depending on the position of the mechanical interaction, there is a tendency for the effect to be more prevalent with current flow in one direction than with current flow in the other direction. This is emphasised with respect to *Figure 10b*. On this occasion, the point of mechanical interaction is close to the supply rails therefore virtually all of the current will flow directly to the point of mechanical interaction in the upper layer, as illustrated by flux line **10021** with a similar effect occurring in conductive layer **202**, with a current flowing directly away from the point of mechanical interaction as illustrated by flux line **10022**.

In the resistive modelling described with reference to *Figure 3*, no account was taken of this second potential method for current flow, as illustrated by flux lines **1001, 1002, 1003** and **1004**. A revised model is therefore illustrated in *Figure 11*, in which potentiometers **1101**, **1102** and **1103** are substantially similar to potentiometers **301, 302** and **303**. However, in order to model the activity of the device in accordance with *Figure 10a* and *10b*, the first shunt resistor **1111** is placed across potentiometer **1101** and a second shunt resistor **1112** is placed across resistor **1102**. Such an arrangement introduces greater complexity in terms of producing accurate results of z values. Furthermore, relationships for combining the two measurements must be re-evaluated. In particular, relationship **301** is based on a more simplistic model and will not strictly hold true for the model illustrated in *Figure 11*.

A solution to this problem is provided by fabricating the conductive layers with anisotropic conductivity. In particular, it is desirable to measure resistance in the linear direction between the contacting portions, such as **216** and **217** this effectively minimises the resistances 1111 and 1112. It is undesirable to introduce resistive effects perpendicular to this direction. Consequently, the material is fabricated with a greater resistivity in the desired linear direction (horizontal in the first later **201** shown in *Figure 10a* and vertical in layer **202** shown in *Figure 10a*) while resistance is reduced (ie conductivity increased) in a perpendicular direction.

The upper and lower fabric layers **201** and **202** are shown separately in *Figure 12*. The fabric layers **201** and **202** are plain weaves having conductive fibres in both the warp and the weft directions and are conductive in all directions along the respective layers. In *Figure 12*, the warp fibres **1201** of layer **201** are shown approximately horizontal and extend between two contacting portions **216** and **217**, while the weft fibres **1202** are parallel to the contacting portions **216** and **217** and are shown approximately vertical. In layer **202**, the substantially vertical warp fibres extend between the contacting portions **218** and **219**, while the weft fibres **1202** are parallel to the contacting portions **218** and **219** and are shown approximately horizontal.

Layers **201** and **202** have anisotropic conductivity. In particular, layers **201** and **202** are more conductive in the directions parallel to their respective contacting portions. Thus, when the detector is operated and a voltage gradient is applied between a pair of contacting portions on the same layer, the respective layer is most conductive in the direction perpendicular to the voltage gradient and less conductive parallel to the voltage gradient. To achieve the desired anisotropic conductivity, the warp fibres are chosen to be of a higher resistance that the weft fibres. For this reason, the warp fibres **1201** are 24 decitex nylon 6 fibres (obtainable from BASF and identified by the designation F901) and are generally available for use in electrostatic dicipation applications. The weft fibres are 16 decitex monofilament fibres, electrochemically coated with nickel and/or silver, and available under the trademark "XSTATIC" from Sauquoit Industries Inc of Pennsylvania USA. Similar metalised fibres are commonly available and are normally used in electromagnetic interference shielding. Thus, a typical resistivity for a weft fibre is 500 ohms per centimetre, as opposed to approximately 200 Kohms per centimetre for the warp fibre.

In layer **201** and **202** the fabric is woven with the same average spacing of 7.3 fibres per millimetre for both the weft and the warp. Consequently, due to different resistivity of the warp and weft fibres, the sheet resisitivity of the layers in the directions parallel to the contacting portions is approximately 400 times less than the sheet resistivity in the perpendicular direction.

In an alternative embodiment, the outer fabric layers **201** and **202** are replaced by outer fabric layers **1301** and **1302** similar to that of layers **201** and **202**, except for the type of fibres used in the weft and in the warp. Thus, contacting portions **1303** and **1304** are located along opposing edges of layer **1301** and contact conductive fibres within said layer, while contacting portions **1305** and **1306** are located along the alternative opposing edges of the layer **1302** and make electrical contact with conductive fibres within layer **1302**.

Outer layer **1301** includes conductive fibres **1307** that conduct in the direction of the current flowing from contacting portion **1303** to contacting portion **1304**. Cross threads **1308** conduct in a direction perpendicular to this one and have the effect of insuring a linear voltage gradient across the sheet, even when the resistance of connections between lateral fibres **1307** with a contacting portion **1303** and **1304** are variable; as would be expected in a manufacturing process.

Insulating fibres **1309** are used between adjacent parallel conducting fibres **1307** in the warp direction and between adjacent parallel conducting fibres **1308** in the weft direction. Anisotropic conductivity is achieved, in the present embodiment, by selecting a different ratio of conductive fibres **1307** and **1308** to non-conductive fibres **1309** for each of the warp and weft directions. Thus, in a direction perpendicular to the contacting portions **1303** and **1304**, which is horizontal in the drawing of layer **1301** shown in *Figure 4*, an insulating fibre alternates with a conducting fibre **1302**. There is an equal quantity of both. However, in the perpendicular direction, there are two conducting fibres **1308** for each parallel insulating fibre **1309**. Thus, when the sensor is operated, in the direction perpendicular to the applied current flow, or the direction perpendicular to the voltage gradient, conductivity is increased.

Outer fabric layer **1302** has a similar structure to layer **1301** but is rotated through 90 degrees. Consequently, the weave includes weft fibres which are substantially parallel to contacting portions **1305** and **1306** and warp fibres which are perpendicular to contacting portions **1305** and **1306**. The layer **1302** is anisotropic in a similar manner to layer **1301**, since its weave contains two conductive fibres **1308** for every insulating fibre **1309** in the weft, while containing an equal number of conducting fibres **1307** to insulating fibres **1309** in the warp.

In this embodiment, the conducting fibres **1307** and **1308**, in both the weft and warp directions, may be of equal resistivity since the anisotropic conductivity of the layers is achieved by selection of the ratios of conductive fibres to insulating fibres. Therefore, a similar carbon coated nylon fibre may be used in both the weft and in the warp directions of the weave.

By making two current measurements and processing the results in combination, it is possible to achieve improved accuracy, in terms of assessing the extent of a mechanical interaction. The accuracy of this measurement may be improved further by using anistropic layers which have greater conductivity in directions perpendicular to the current flow. Furthermore, further accuracy may be achieved by modifying the way in which the measurements are processed in combination. In particular, better results are achieved if the reciprocals of the measurements are added and then the resulting total itself reciprocated; akin to combining resistances in parallel as distinct to combining resistances in series.

Current flux for upper layer **201** and current flux for lower layer **202** are illustrated in *Figure 14a* where layers **201** and **202** are constructed using anisotropic fabrication. The arrangement in *Figure 14a* illustrates current fluxes in response to a mechanical interaction substantially similar to that shown in *Figure 10a* and with substantially similar voltages applied to the electrical contacts. Similarly, **1401** and **1402** are illustrated in *Figure 14b* with a similar mechanical interaction but with the current flows reversed so as to be substantially similar to the arrangement shown in *Figure 10b*.

In the arrangement shown in *Figure 14a*, current flows from in layer **1402** a conductive portion **1418** towards a position of mechanical interaction **1403**. The current flows from portion **1418** in substantially parallel lines **1404**, some of which go directly towards the point of mechanical interaction **1403**. In other situations, the flux is diverted and then traverses substantially perpendicular to lines **1404** along lines **1405**. Current easily flows in this direction given the relatively lower resistivity of the fabric layer in this direction.

In the upper layer **1401**, the current emerges at the position of mechanical interaction **1403** and again easily moves outwards in the perpendicular direction along the lines of flux **1411**. Current flow towards the portion **1417** then takes place along substantially parallel lines of flux **1412**.

A resulting flow of current occurring when the direction of flow is changed is shown in *Figure 14b*, which represents a condition similar to that shown in *Figure 10b* except that anisotropic conducting layers are being used. On this occasion, current initially flows from contacting portion **1416** towards the point of mechanical interaction **1403**. Again, the flow of current from portion **1416**, indicated by flux lines **1421** is substantially parallel, whereafter perpendicular flow, illustrated by flux lines **1422** occurs in the perpendicular direction towards the position of mechanical interaction **1403**.

On the lower conducting layer **1402** the current emerges at the position of mechanical interaction **1403** and then easily conducts in the perpendicular direction, as illustrated by flux line **1431**. The current is then directed towards contacting portion **1419** in substantially parallel lines of flux **1432**.

Thus, by employing anisotropic layers with lower resistance in the direction parallel to the contacting portions in the respective layers, resistors **1111** and **1112** are effectively eliminated from the model. In this way, measurements of the size of the mechanical interaction are significantly more accurate when mechanical interaction are closer to the edges of the device. This also ensures that relationship **310** holds true and in combination a substantially more reliable device is achieved.

Claims

1. A fabric-made position detector, having

a first fabric electrically conducting layer;

a second fabric electrically conducting layer, wherein

said first electrically conducting layer has a first electrical contact and a second electrical contact and

said second electrically conducting layer has a third electrically conducting contact and a fourth electrically conducting contact;

potential applying means for applying potential across said first contact and said third contact to produce a first current and for applying a potential across said second contact and said fourth contact to produce a second current;

current measuring means for measuring said first current to produce a first current value and for measuring said second current to produce a second current value; and

processing means configured to produce a property value indicating a property of a mechanical interaction by processing said first current value in combination with said second current value.

2. A fabric-made position detector according to claim 1, wherein said first fabric electrically conducting layer and/or said second fabric electrically conducting layer have different conductivities in different directions.

3. A fabric-made position detector according to claim 2, wherein layer conductivity of said first layer in a first direction connecting said first contact with said second contact is lower than the conductivity in a second direction perpendicular to said first direction.

4. A fabric-made position detector according to claim **2** or claim **3**, wherein said different conductivities are achieved by using different yarns having different conductivities.

5. A fabric-made position detector according to claim **2** or claim **3**, wherein said different conductivities are achieved by using different mixtures of conducting and non-conducting yarn.

6. A fabric-made position detector according to claim **1**, wherein said property value is determined as an average of said first current value and said second current value.

7. A fabric-made position detector according to claim **1**, wherein said property value is determined by combining a reciprocal of said first current value with a reciprocal of said second current value.

8. A fabric-made position detector according to claim **1**, wherein

a central layer is disposed between said first fabric electrically conducting layer and said second fabric electrically conducting layer, said central layer including conducting means;

a first insulating separating means disposed between said first conductive outer layer and said conducting means; and

a second insulating separating means disposed between said second conductive outer layer and said conducting means; wherein

said conducting means provides a conductive path between said first conducting outer layer and said second conducting outer layer at the position of a mechanical interaction.

9. A fabric-made position detector according to claim **8**, wherein said first insulating means comprises a first separate insulating layer and said second insulating means comprises a second separate insulating layer.

10. A fabric-made position detector according to claim **1**, further including

a compressible inner layer disposed between said first fabric conducting layer and said second fabric conducting layer having a plurality of conductive fibres or particles such that a conductive path is provided through said fibres or particles when said insulating material is placed in compression.

11. A method of detecting a mechanical interaction with respect to a position detecting device, wherein said position detecting device is configured to detect the position of a mechanical interaction by measuring electrical potentials applied across electrically conducting layers, characterised by the steps of

measuring a first current when an electrical potential is applied between a first contact of a first conducting layer and a third contact of a second conducting layer while disconnecting connections to a second contact of the first conducting layer and a fourth contact of said second conducting layer;

measuring a second current when an electrical potential is applied between said second and said fourth contacts while disconnecting connections to said first and said third contacts; and

processing said first current measurement in combination with said second current measurement to derive an output indicative of a characteristic of said mechanical interaction.

12. A method of detecting mechanical interaction according to claim **11**, wherein said first fabric electrically conducting layer and/or said second fabric electrically conducting layer have different conductivities in different directions.

13. A method according to claim **12**, wherein layer conductivity of said first layer in a first direction connecting said first contact with said second contact is lower than conductivity in the second direction perpendicular to said first direction.

14. A method according to claim **12** or claim **13**, wherein said different conductivities are achieved by using different yarns having different conductivities.

15. A method according to claim **12** or claim **13**, wherein said different conductivities are achieved by using different mixtures of conducting and non-conducting yarn.

16. A method according to claim **11**, wherein said property value is determined as an average of said first current value and said second current value.

17. A method according to claim **11**, wherein said property value is determined by combining reciprocals of measured values.

18. A method of detecting a mechanical interaction according to claim **11**, wherein

a central layer is disposed between said first fabric electrically conducting layer and said second fabric electrically conducting layer, said central layer including conducting means;

a first insulating separating means disposed between said first conductive outer layer and said conducting means; and

a second insulating separating means disposed between said second conductive outer layer and said conducting means; wherein

said conducting means provides a conductive path between said first conducting outer layer and said second conducting outer layer at the position of a mechanical interaction.

19. A method according to claim **18**, wherein said first insulating means comprises a first separate insulating layer and said second insulating means comprises a second separate insulating layer.

20. A method according to claim **11**, further including a compressible inner layer disposed between said first fabric conducting layer and said second fabric conducting layer having a plurality of conductive fibres or particles such that a conductive path is provided through said fibres or particles when said insulating material is placed in compression.

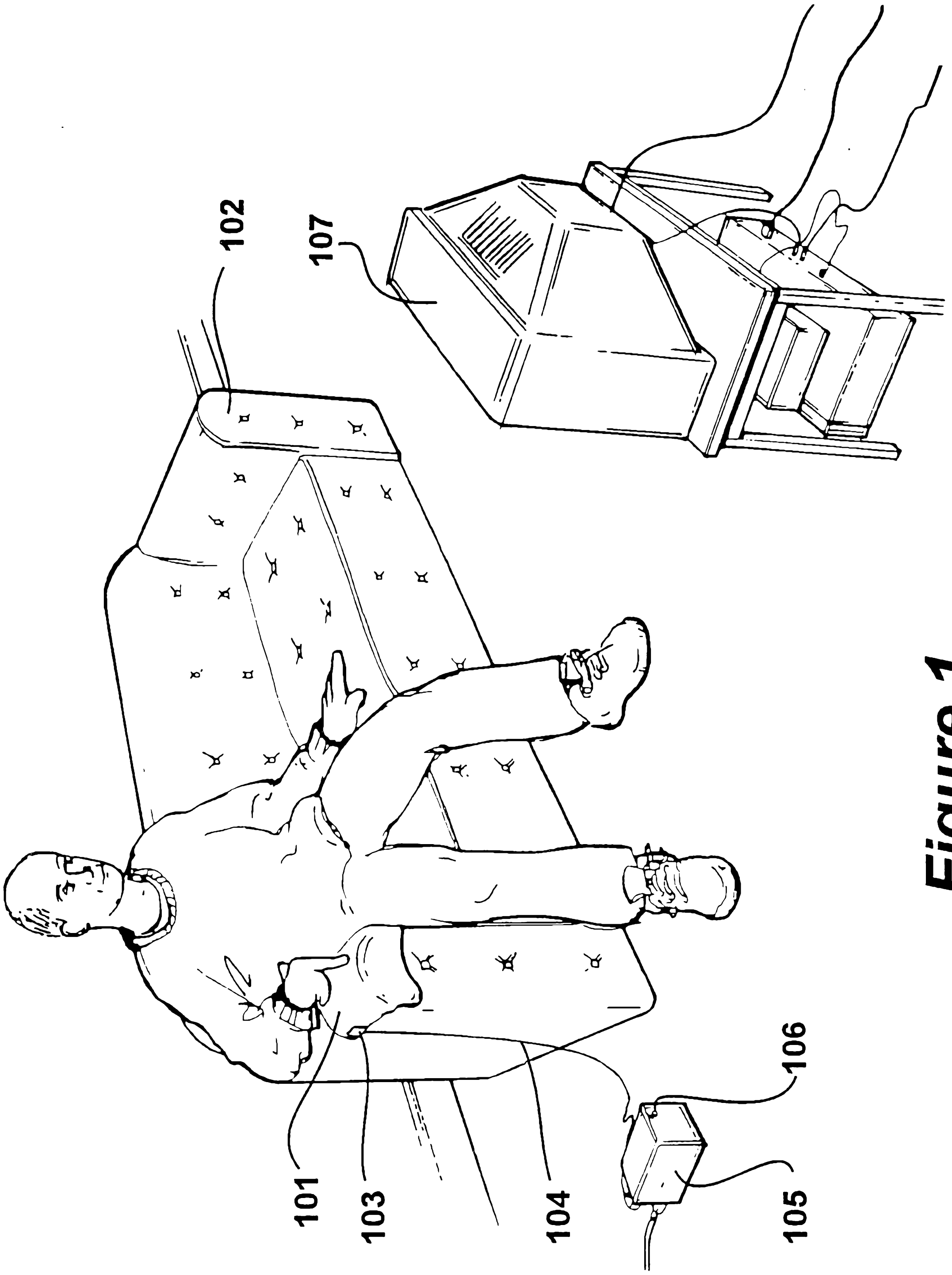
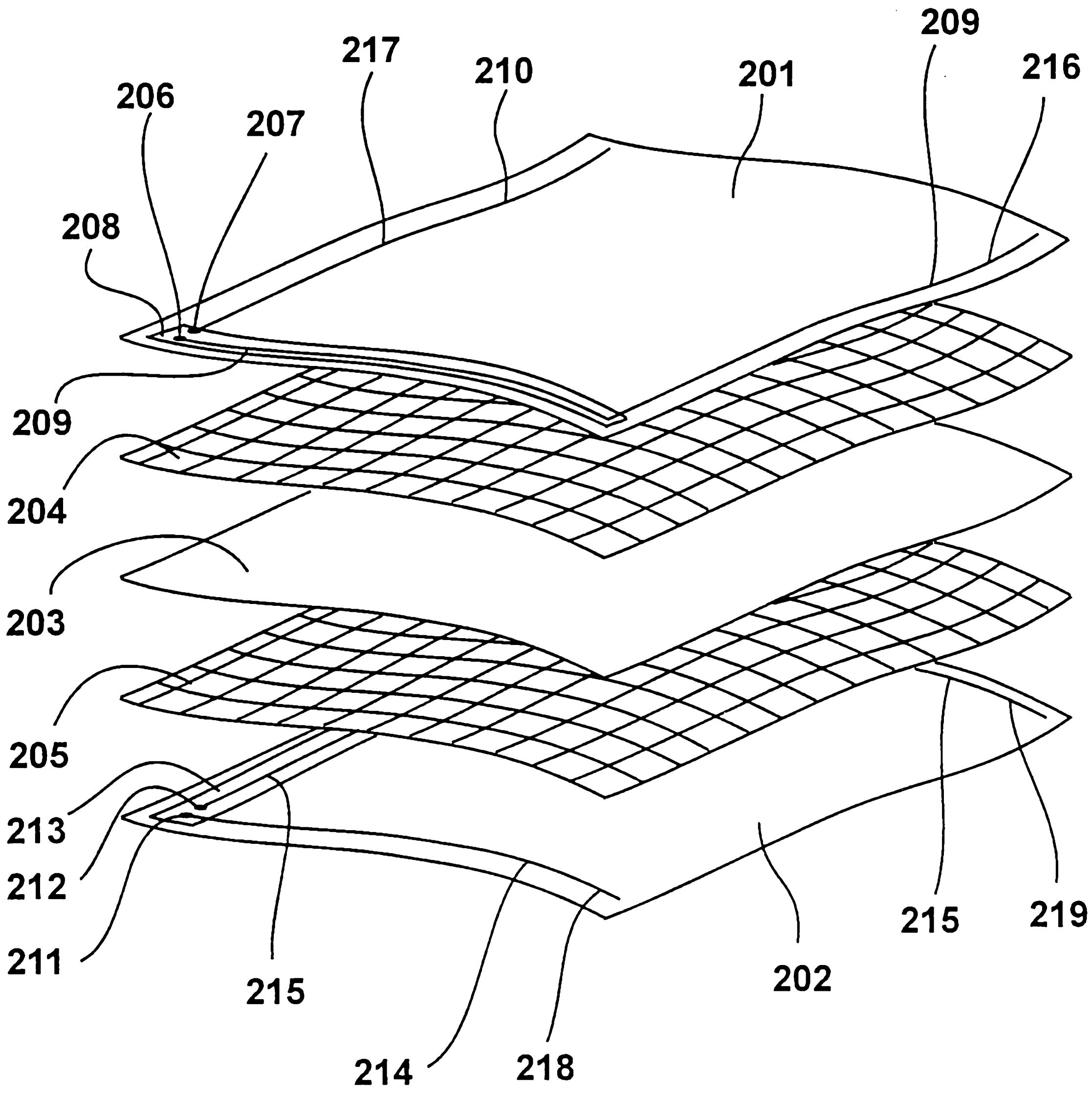


Figure 1



209
217
210
201
216
206
207
208
209
204
203
205
213
212
211
215
214
218
202
215
219

Figure 2

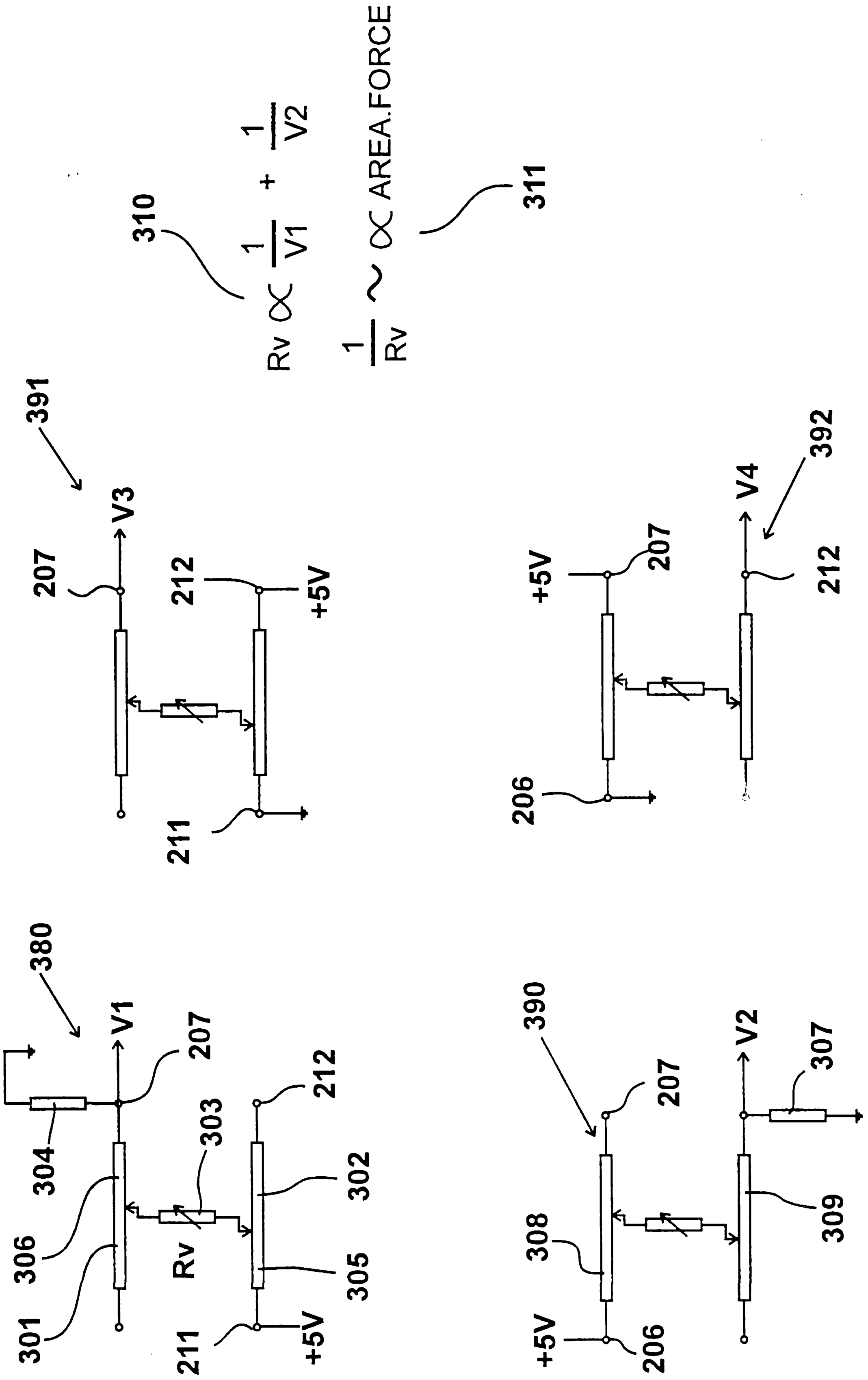

310
Rv ∝ 1/V1 + 1/V2
1/Rv ~ ∝ AREA.FORCE
311
391
V3
207
212
+5V
211
392
V4
+5V
207
212
206
380
V1
207
212
304
303
302
306
Rv
305
301
211
+5V
390
V2
207
307
308
309
+5V
206

Figure 3

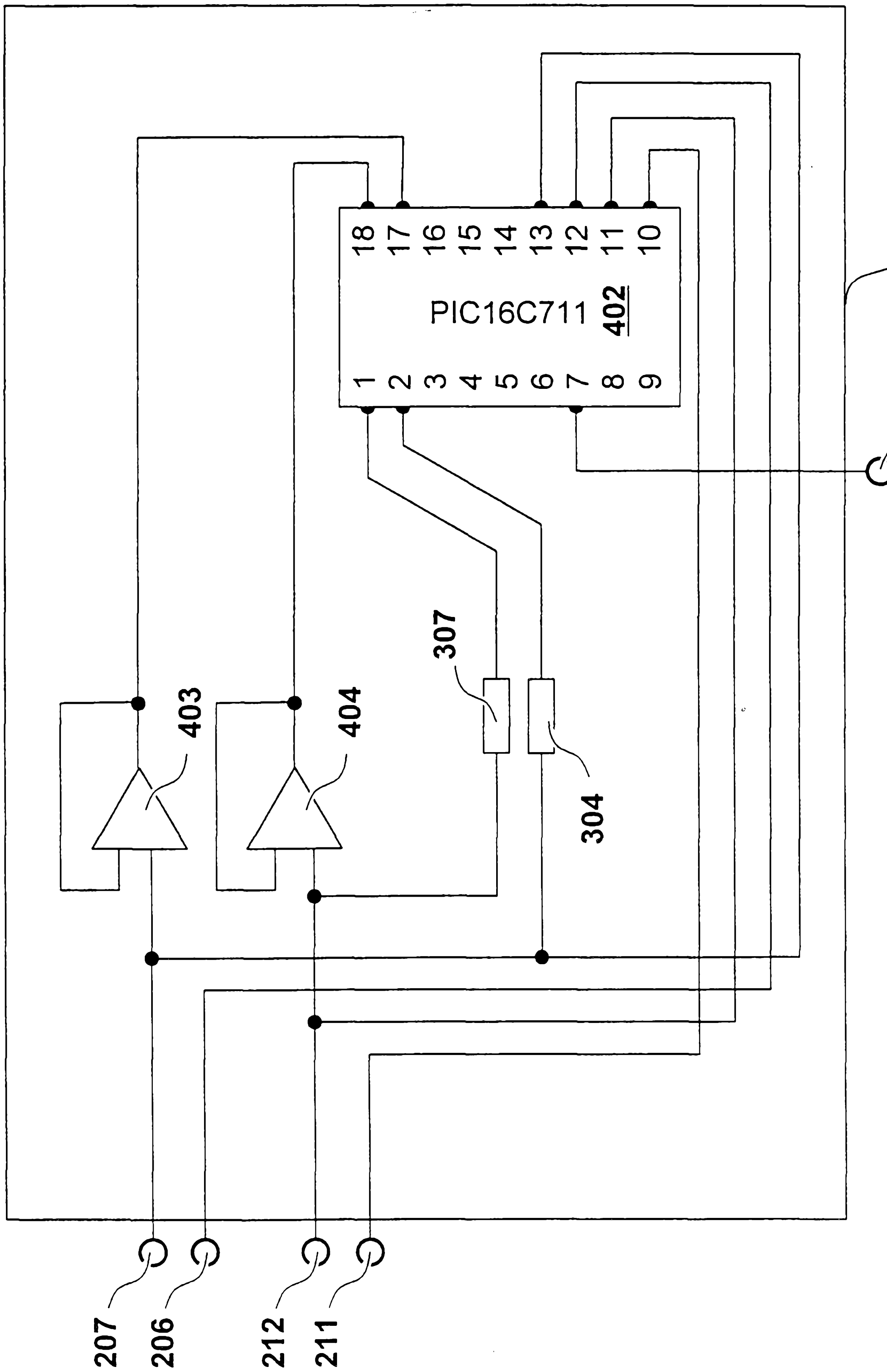

PIC16C711
402
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
103
401
403
404
307
304
207
206
212
211

Figure 4

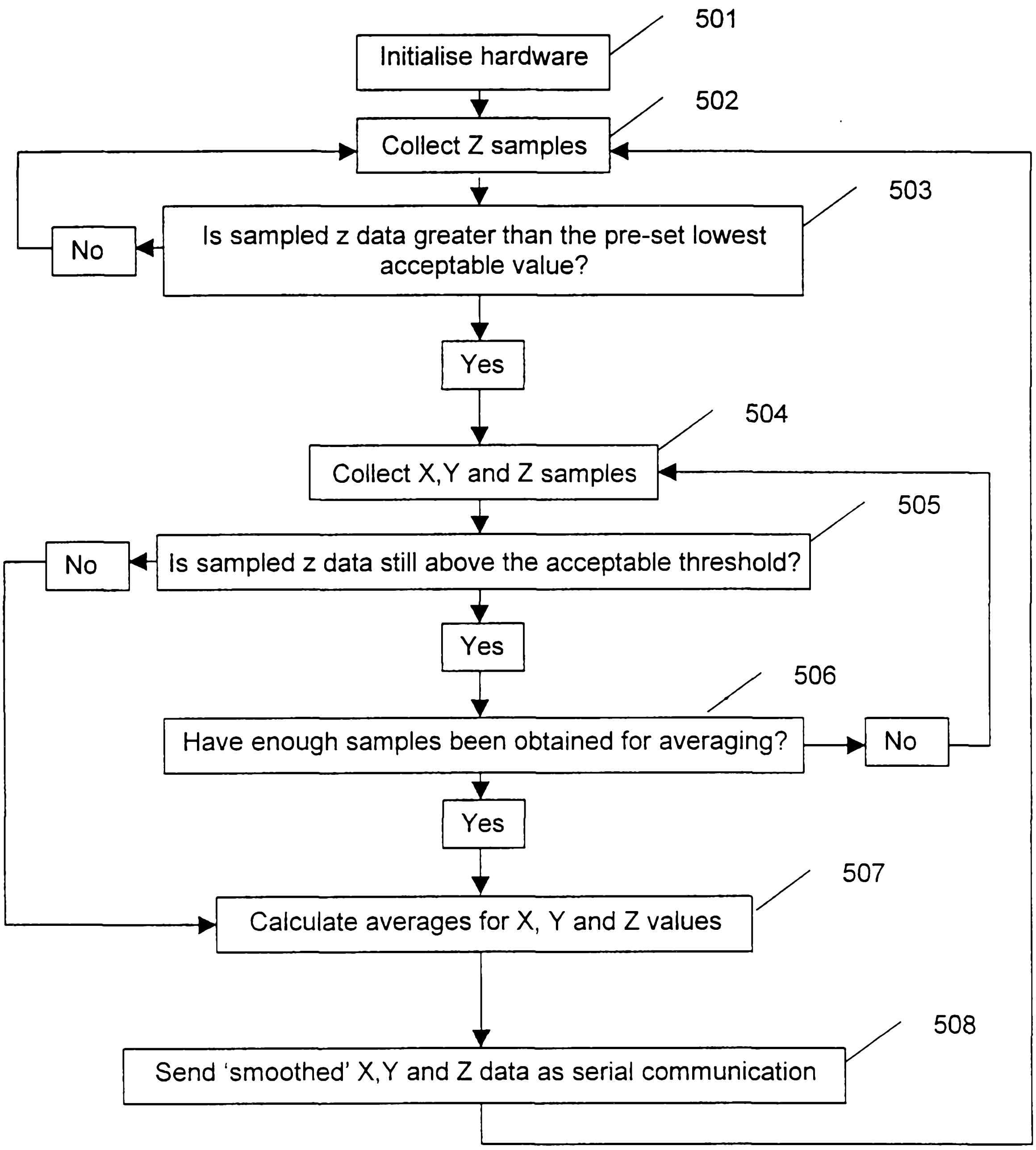
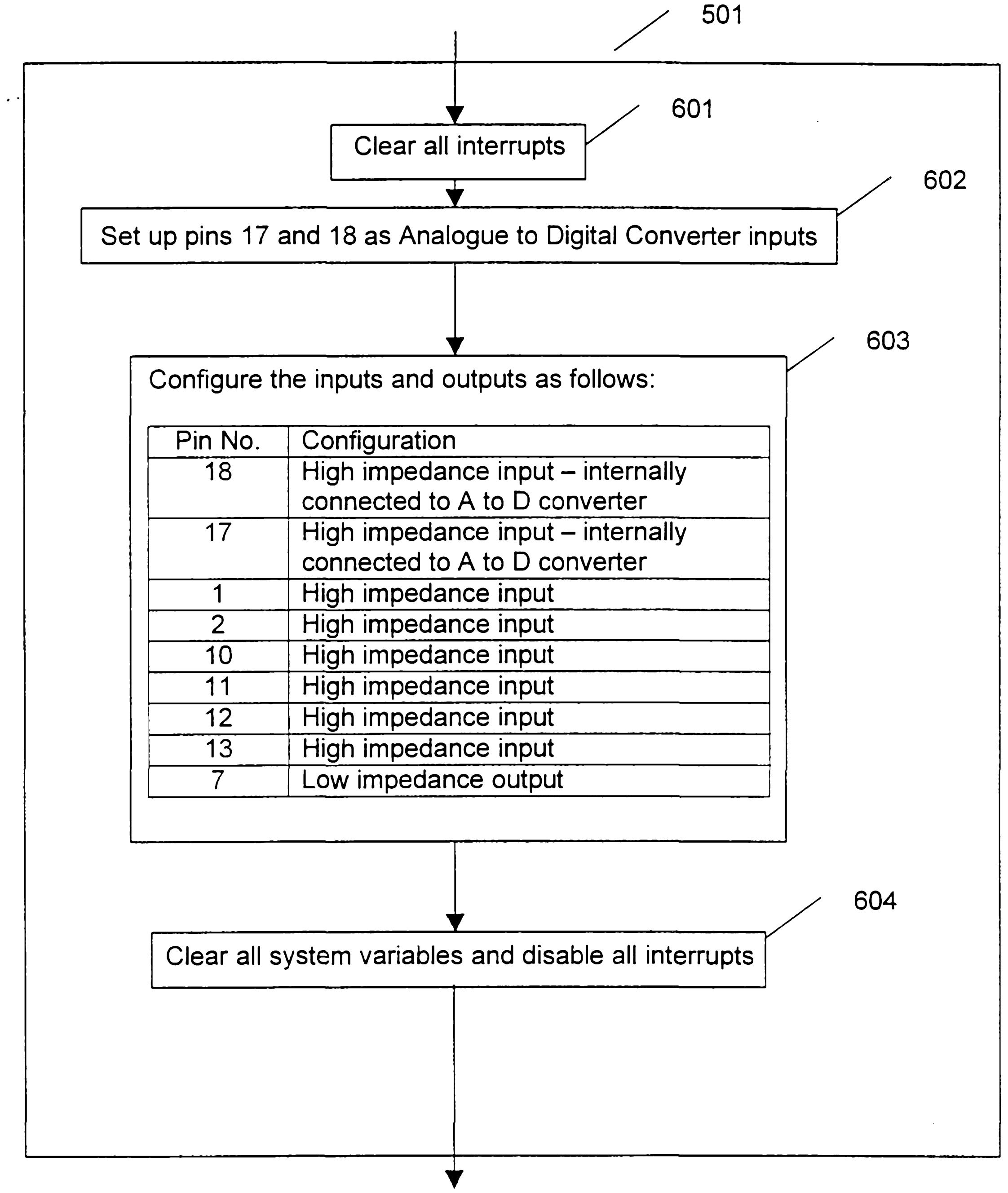

501
Initialise hardware
502
Collect Z samples
503
Is sampled z data greater than the pre-set lowest acceptable value?
No
Yes
504
Collect X,Y and Z samples
505
Is sampled z data still above the acceptable threshold?
No
Yes
506
Have enough samples been obtained for averaging?
No
Yes
507
Calculate averages for X, Y and Z values
508
Send 'smoothed' X,Y and Z data as serial communication

Figure 5



Pin No.	Configuration
18	High impedance input – internally connected to A to D converter
17	High impedance input – internally connected to A to D converter
1	High impedance input
2	High impedance input
10	High impedance input
11	High impedance input
12	High impedance input
13	High impedance input
7	Low impedance output

Figure 6

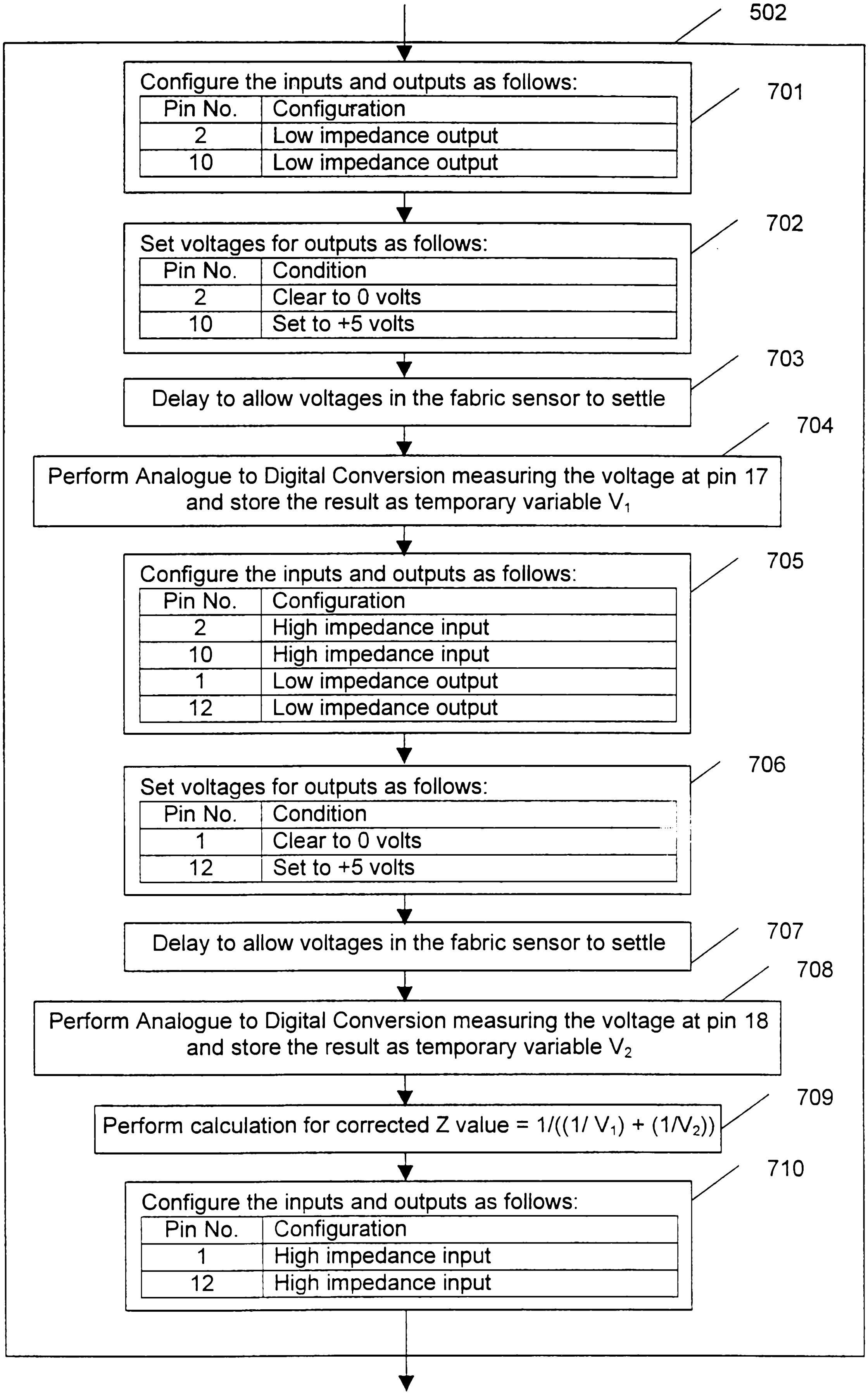

502
Configure the inputs and outputs as follows:
Pin No. | Configuration
2 | Low impedance output
10 | Low impedance output
701
Set voltages for outputs as follows:
Pin No. | Condition
2 | Clear to 0 volts
10 | Set to +5 volts
702
Delay to allow voltages in the fabric sensor to settle
703
Perform Analogue to Digital Conversion measuring the voltage at pin 17 and store the result as temporary variable V_1
704
Configure the inputs and outputs as follows:
Pin No. | Configuration
2 | High impedance input
10 | High impedance input
1 | Low impedance output
12 | Low impedance output
705
Set voltages for outputs as follows:
Pin No. | Condition
1 | Clear to 0 volts
12 | Set to +5 volts
706
Delay to allow voltages in the fabric sensor to settle
707
Perform Analogue to Digital Conversion measuring the voltage at pin 18 and store the result as temporary variable V_2
708
Perform calculation for corrected Z value = $1/((1/V_1) + (1/V_2))$
709
Configure the inputs and outputs as follows:
Pin No. | Configuration
1 | High impedance input
12 | High impedance input
710

Figure 7

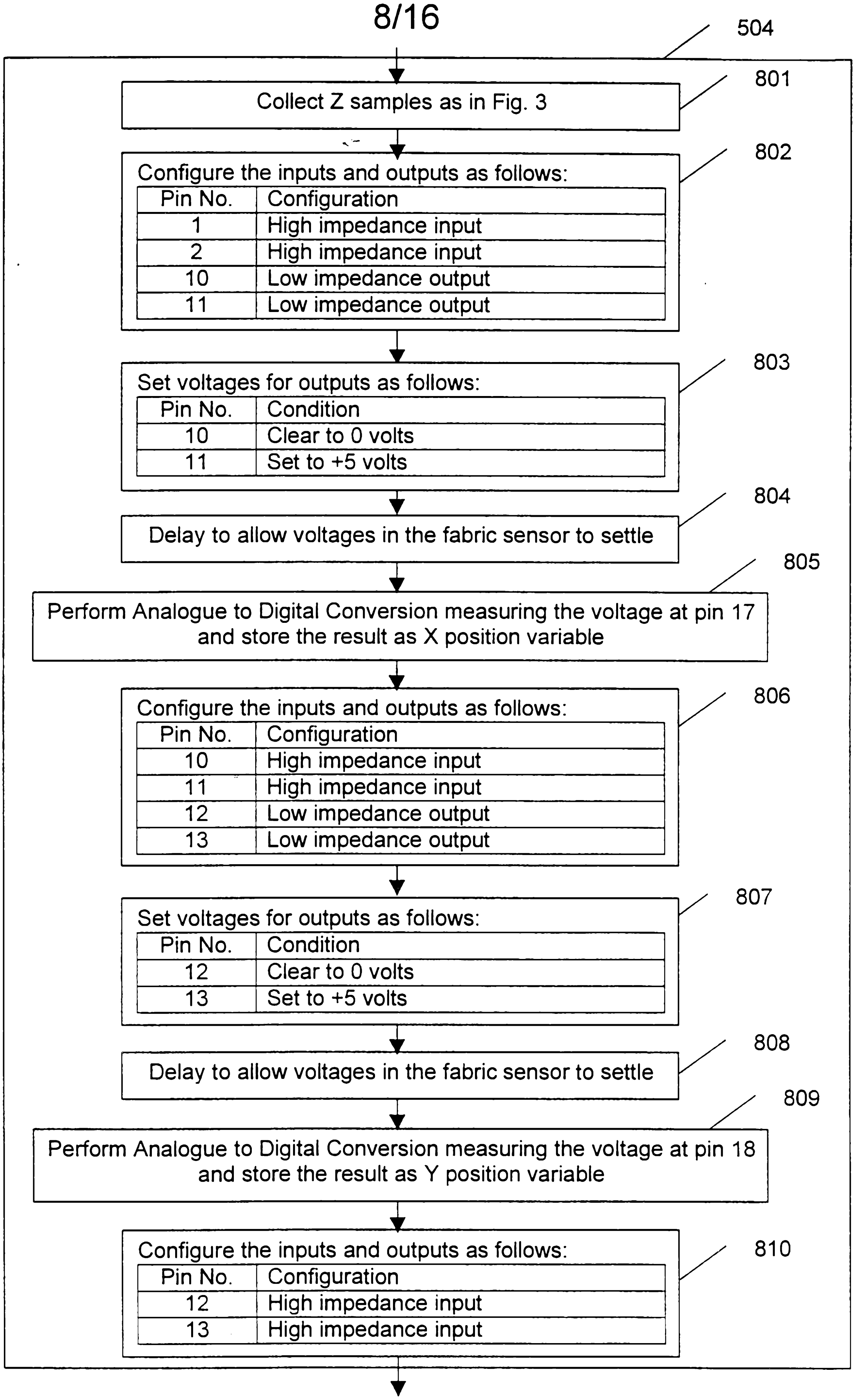

504
801
Collect Z samples as in Fig. 3
802
Configure the inputs and outputs as follows:
Pin No. Configuration
1 High impedance input
2 High impedance input
10 Low impedance output
11 Low impedance output
803
Set voltages for outputs as follows:
Pin No. Condition
10 Clear to 0 volts
11 Set to +5 volts
804
Delay to allow voltages in the fabric sensor to settle
805
Perform Analogue to Digital Conversion measuring the voltage at pin 17 and store the result as X position variable
806
Configure the inputs and outputs as follows:
Pin No. Configuration
10 High impedance input
11 High impedance input
12 Low impedance output
13 Low impedance output
807
Set voltages for outputs as follows:
Pin No. Condition
12 Clear to 0 volts
13 Set to +5 volts
808
Delay to allow voltages in the fabric sensor to settle
809
Perform Analogue to Digital Conversion measuring the voltage at pin 18 and store the result as Y position variable
810
Configure the inputs and outputs as follows:
Pin No. Configuration
12 High impedance input
13 High impedance input

Figure 8

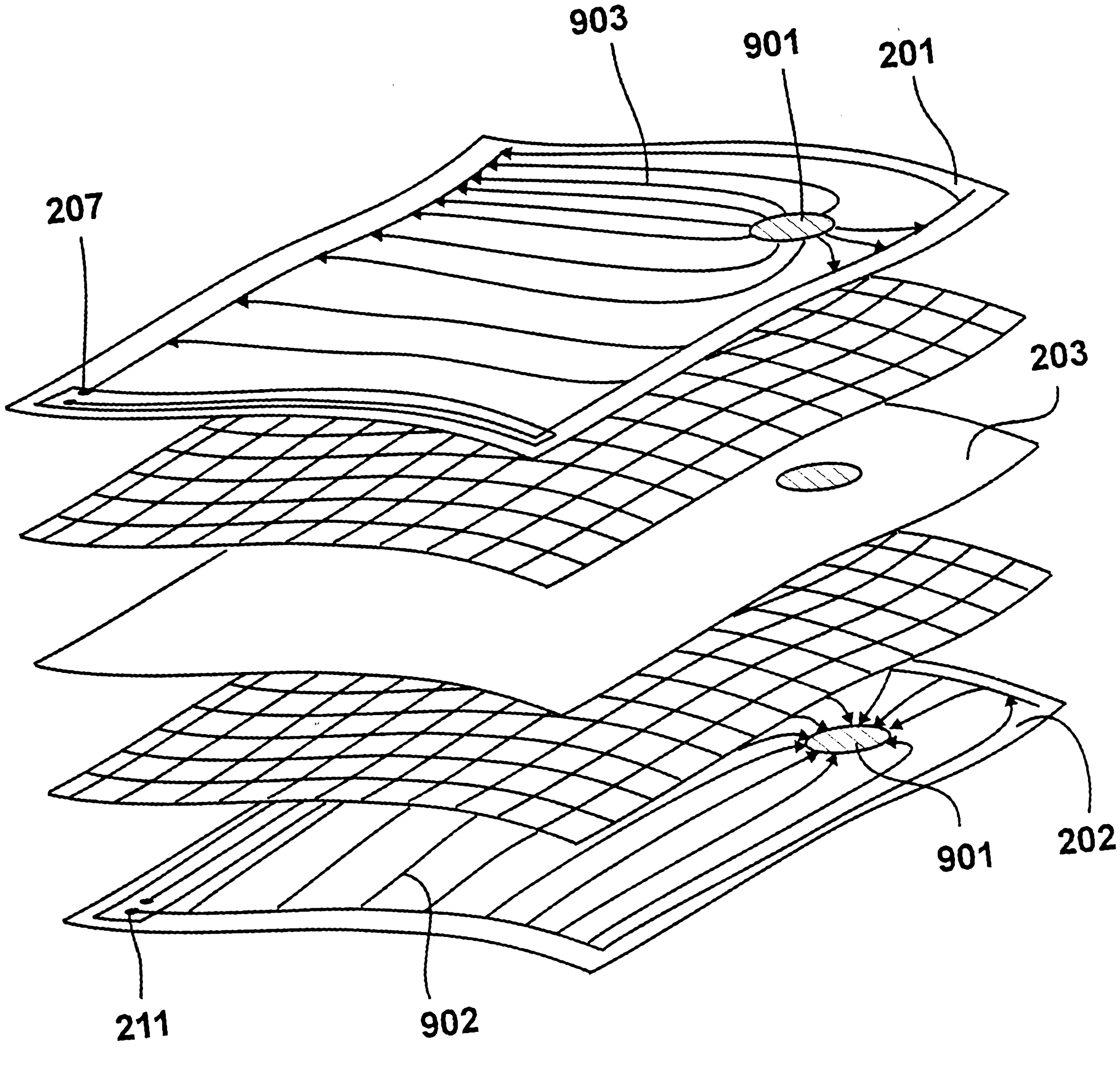


Figure 9

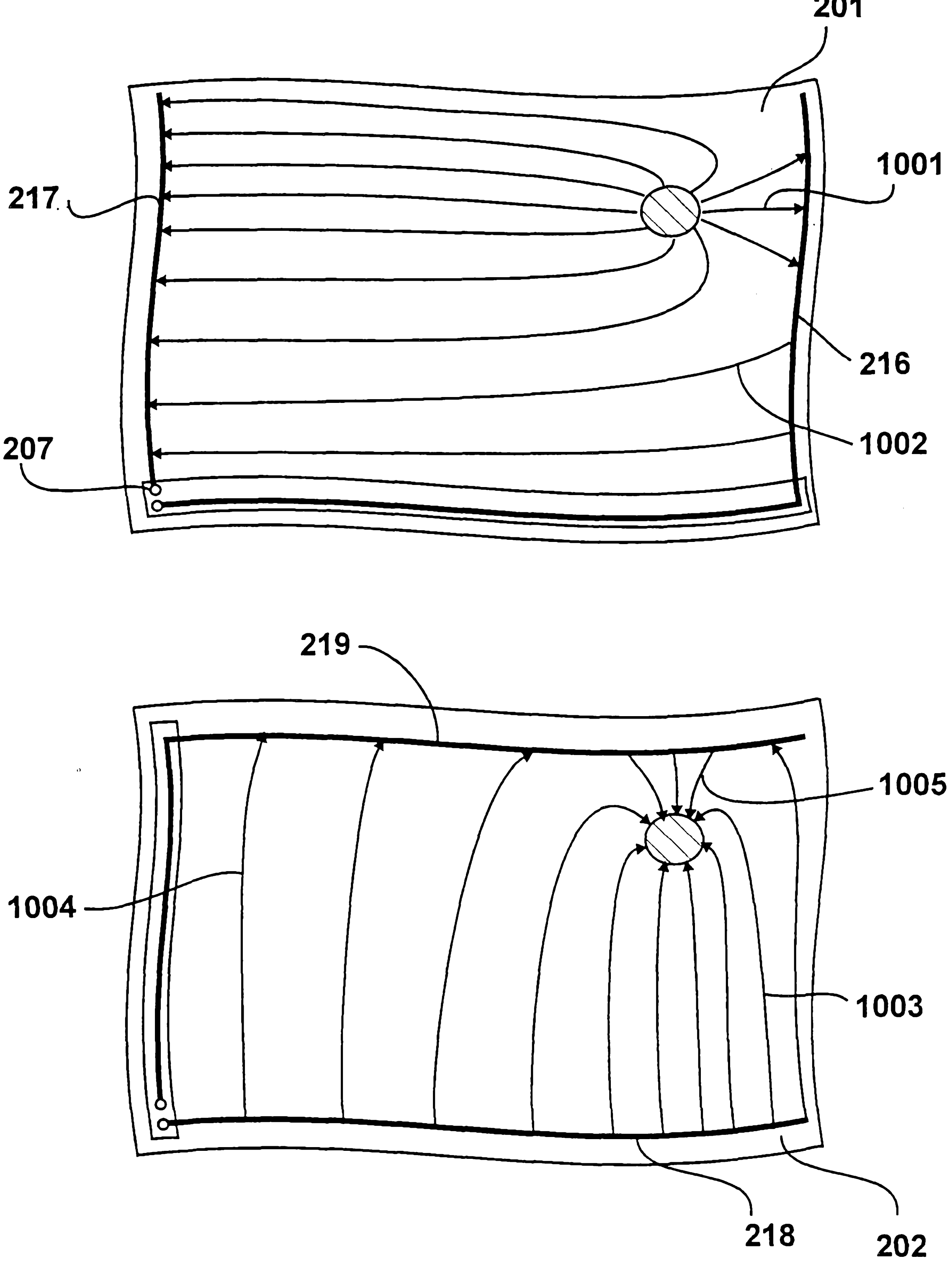


Figure 10A

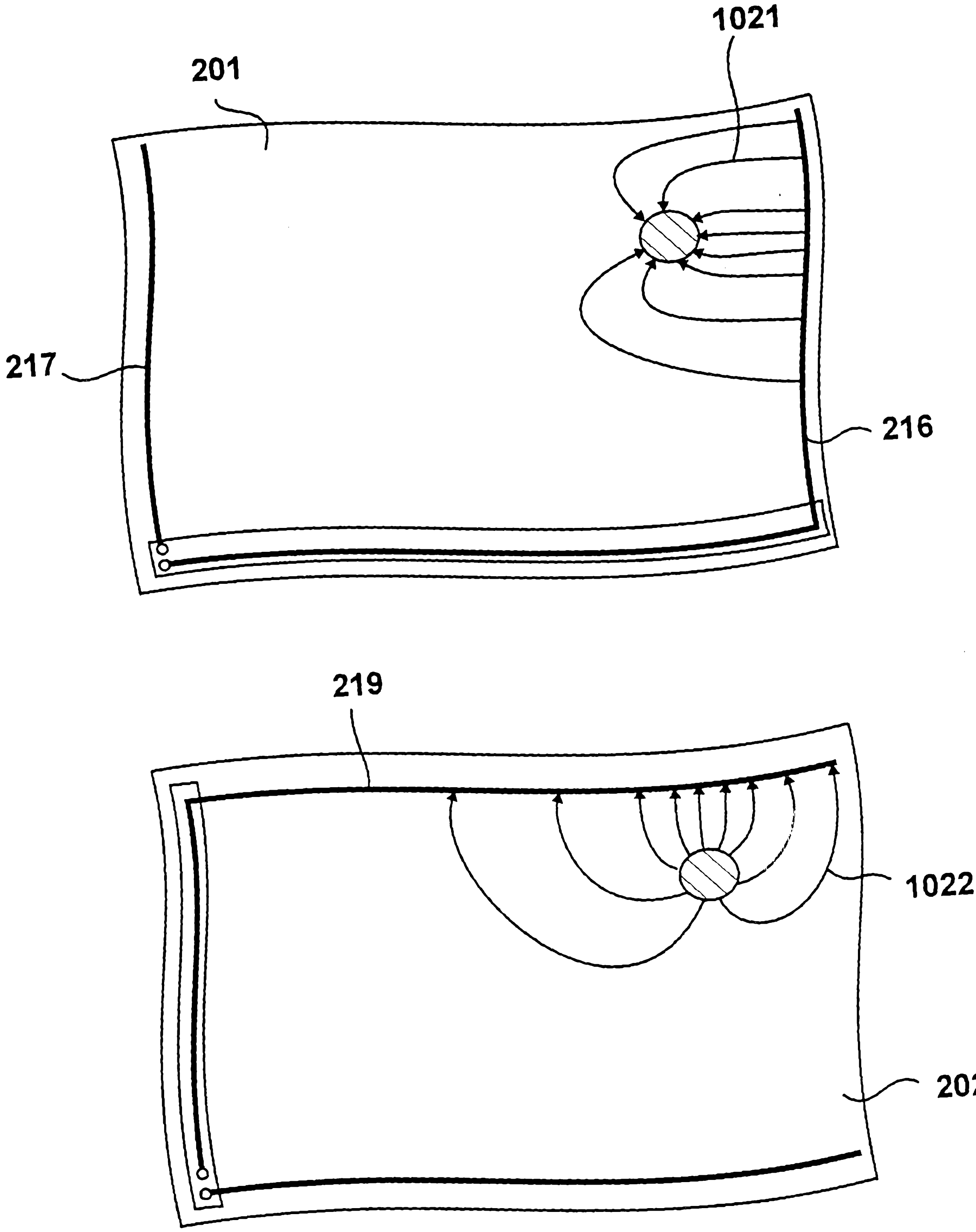


Figure 10B

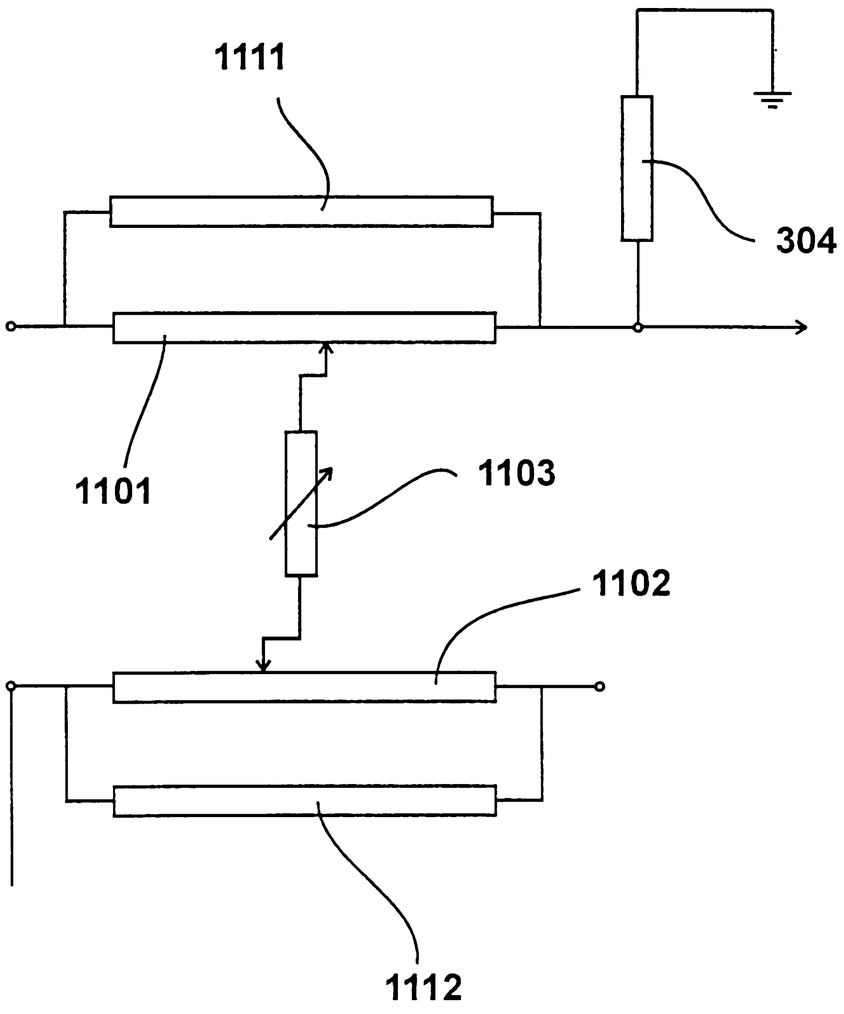


Figure 11

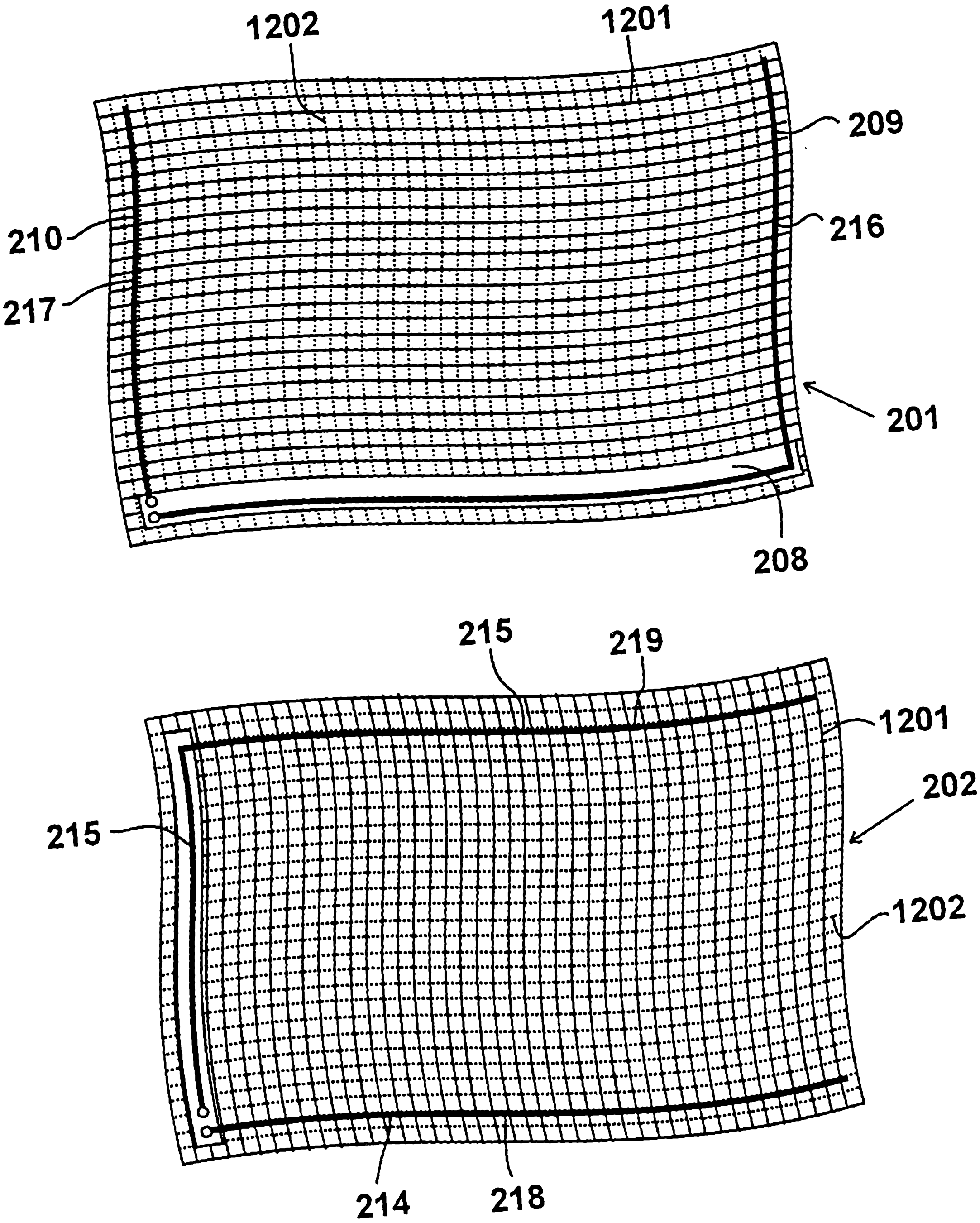

1202
1201
209
210
216
217
201
208
215
219
1201
202
215
1202
214
218

Figure 12

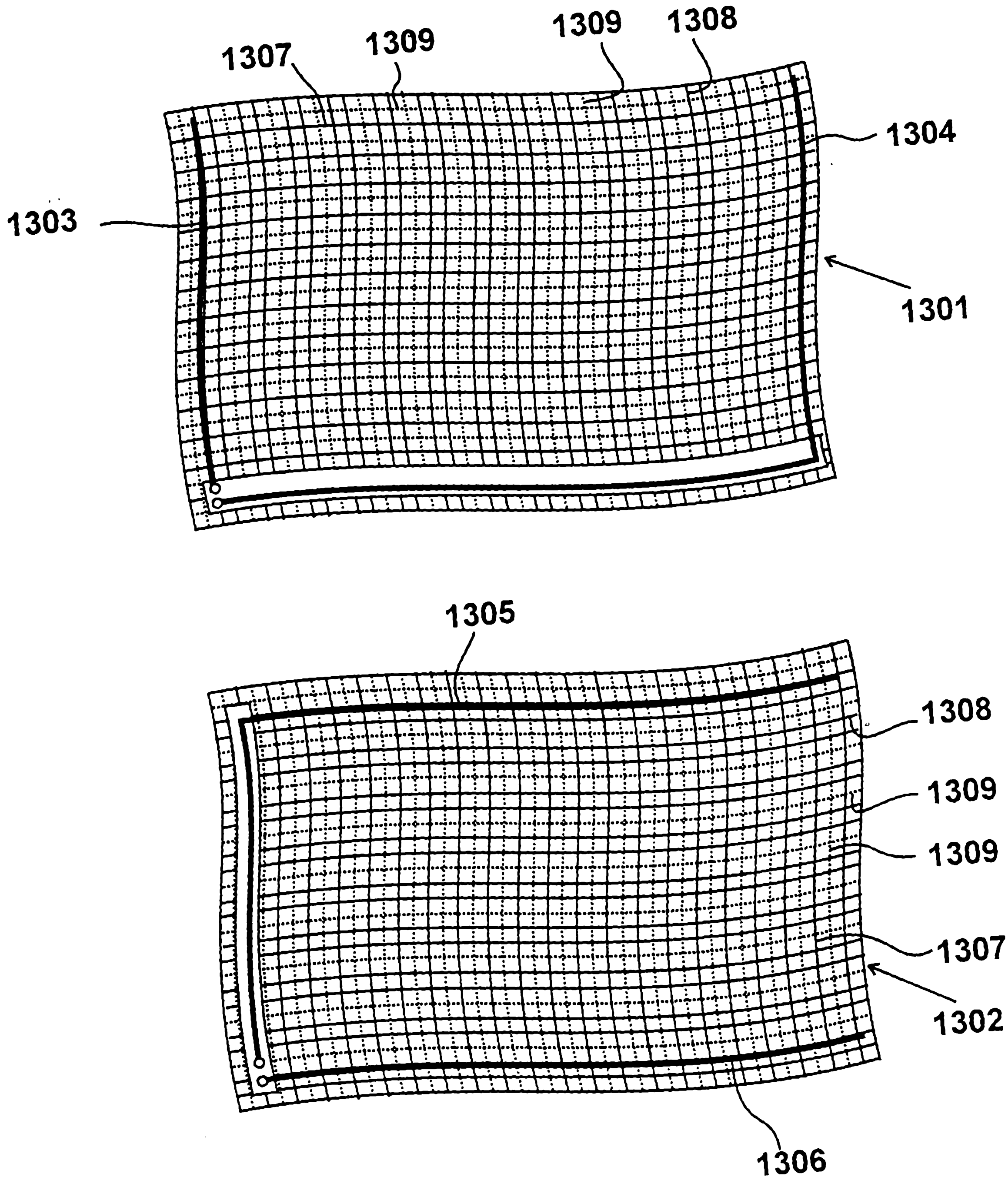
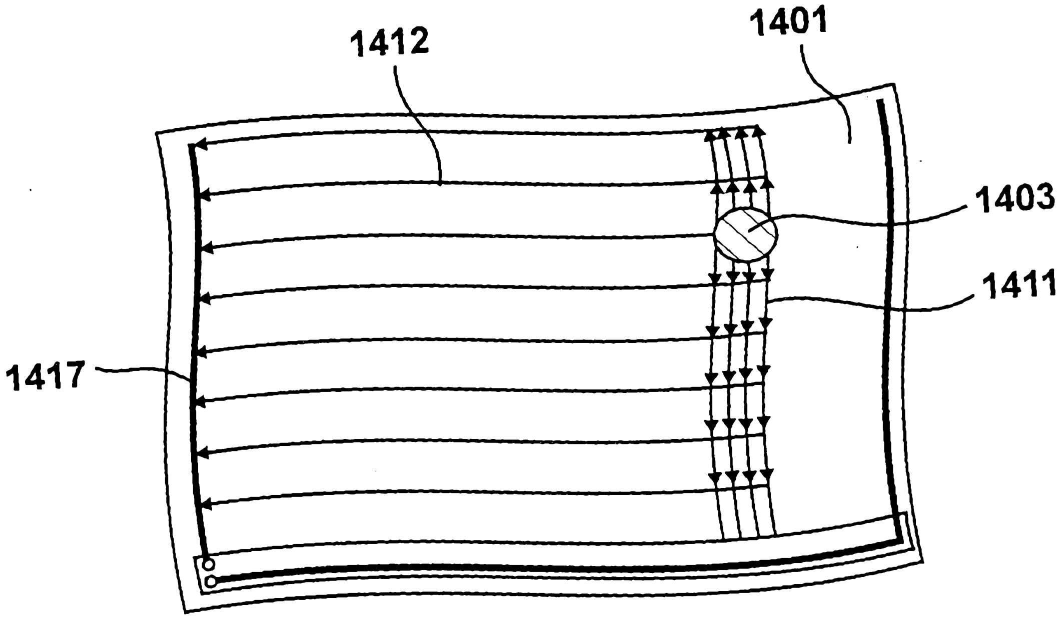

1307
1309
1309
1308
1304
1303
1301
1305
1308
1309
1309
1307
1302
1306

Figure 13



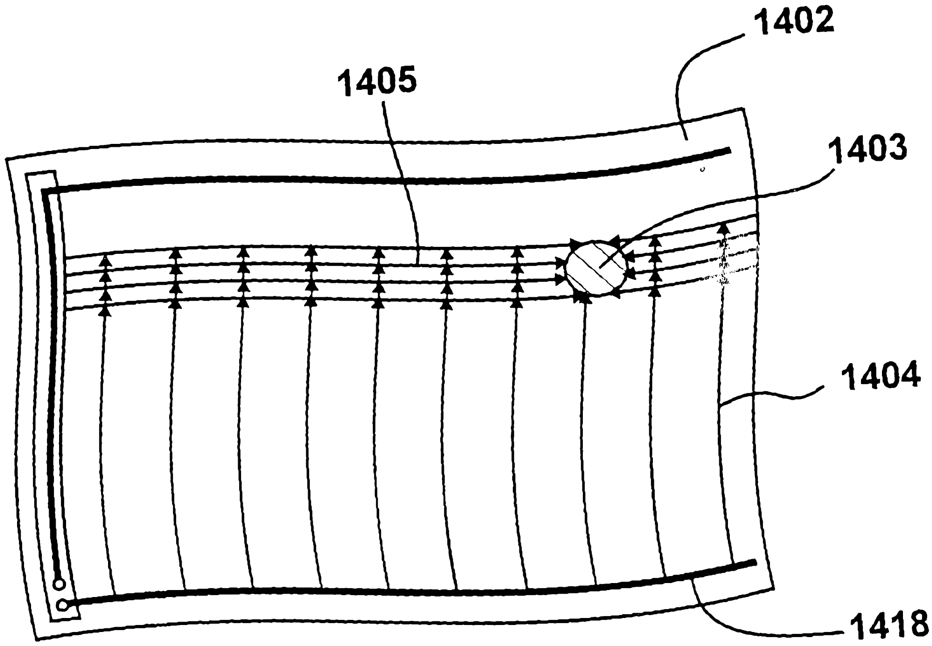


Figure 14A

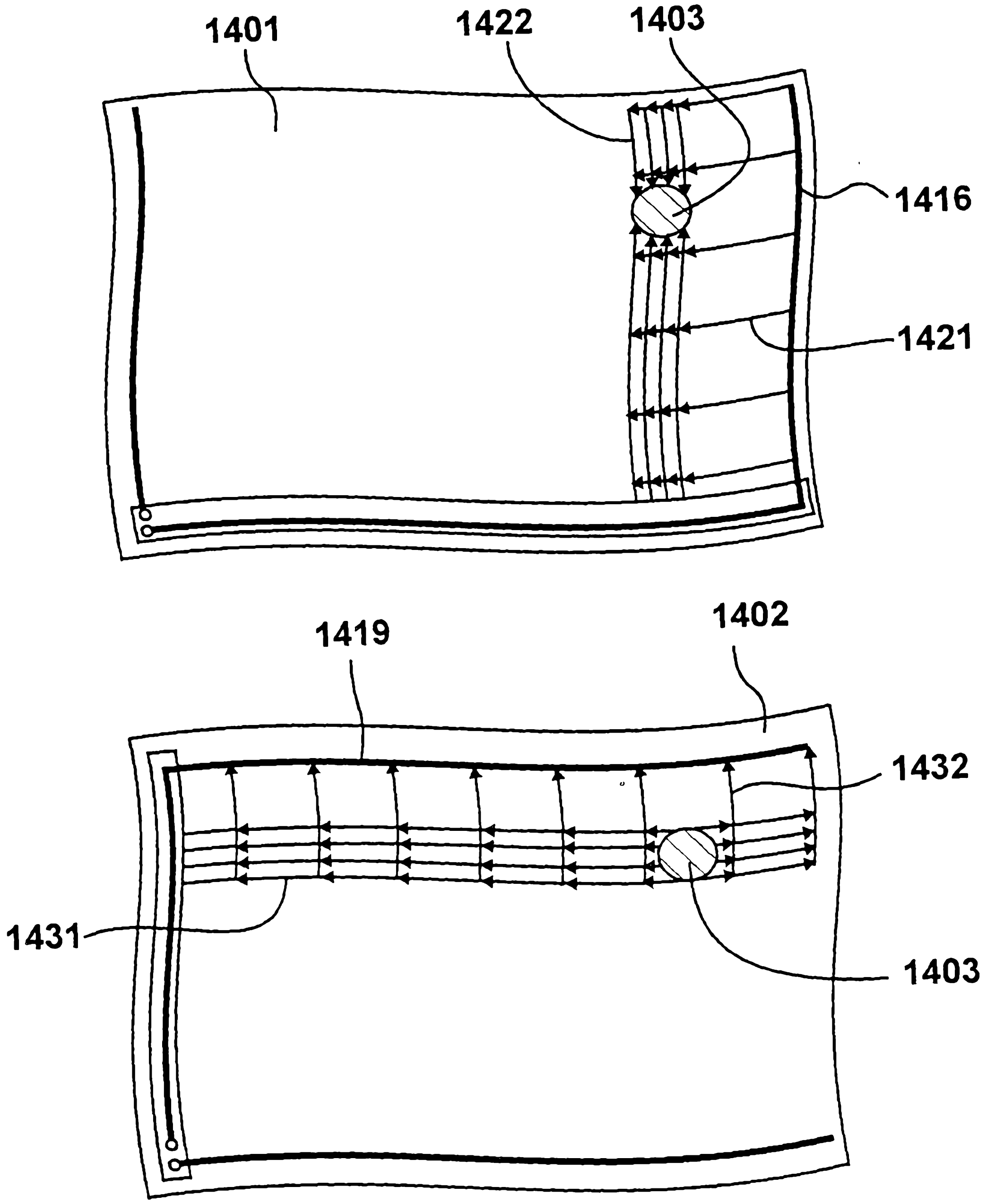


Figure 14B